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A mobile station, a method of transmitting electronic in-
formation, and a communications system
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5   The invention relates to a mobile station adapted to be
used in a radio communications system, said mobile sta-
tion including: receiver means adapted to receive blocks
of distorted information bits at a first rate, and first
detecting means adapted to detect information bits from
10 said distorted information bits.

The invention also relates to a method of transmitting
electronic information from a first communications device
to a second communications device in a radio communica-
15 tions system, and to a communications system.

Often, when transmitting digital information from a first
communications device to a second communication devices,
the information is transmitted as blocks of information
20 bits. For example, in Time Division Multiple Access or
TDMA systems a number of digital signals are interleaved
into a single high-speed channel, i.e. the channel con-
sists of a number of sub-channels providing service to a
number of communications devices instead of one. There-
25 fore, when transmitting information to a given communica-
tion device, the information is transmitted as blocks of
information bits. In TDMA systems the communication is
performed during continuously repeating intervals of time
or so-called time slots in which two devices are able to
30 interconnect, i.e. blocks of information bits are trans-
mitted therebetween at a given rate.

A mobile station or mobile phone capable of transmitting
and/or receiving information such as voice and/or data
35 signals over a cellular communications channel or other
air interfaces comprises a radio transceiver. It is well

known, when transmitting information from a first commu-
nications device, e.g. a base station, to a second commu-
nications device, e.g. a mobile station, via a communica-
tions link in a radio communications system, the signals

5   transmitted are exposed to distortion, e.g. as a result
of intersymbol interference (ISI) introduced by the
physical channel. Hence, the signals received by the re-
ceiver in the second communications device are distorted
versions of the signals originally sent from the first

10   communications device.

Therefore, when blocks of digital information are trans-
mitted from a first communications device to a second
communications device via a communications link or chan-

15   nel, blocks of distorted information bits may be received
in the second communications device. As a consequence,
when receiving blocks of digital information bits, detec-
tion of the information bits has to be performed on the
basis of the received distorted information in order to

20   recover the information bits originally sent, i.e. infor-
mation bits are detected from the received distorted in-
formation bits.

The object of the present invention is to provide an im-
25   proved mobile station of the above-mentioned type.

According to the invention, the object is accomplished by
a mobile station of the above-mentioned type, said mobile
station further including: second detecting means

30   adapted, when the quality of said received blocks of in-
formation bits is above a given level, to detect informa-
tion bits from said distorted information bits using
fewer computation resources than said first detecting
means, and estimation means adapted to estimate the qual-

35   ity of one or more of said received blocks of information
bits and, based thereon, to determine whether to use said

first or said second detecting means when detecting in-
formation bits.

The invention is based on the circumstance that a number
of tasks in a mobile station are implemented in software
and are executed by use of the same processor means, i.e.
to some extent a number of tasks share the computational
resources given in the mobile station. Therefore, compu-
tational resurses may advantageously be moved from one
process to another when possible. This is of major inter-
est in computational limited communications devices, such
as mobile stations, as it enables an optimal use of the
given computational resources. According to the inven-
tion, the computational recourses freed when using the
second detecting means instead of the first detection
means can be used for other purposes in the mobile sta-
tion. Alternatively, the freed computational resources
can be saved resulting in a lower power consumption, and
as a consequence - when the mobile is powered by battery
- will extend the maximum operational time (both talk
time and standby time) between recharges of the battery.

In accordance with an expedient embodiment, said mobile
station is adapted when operated in a first mode in which
said received blocks of information bits are received at
said first rate and said first detecting means is used,
and when said estimated quality is above a predetermined
first threshold, to change to a second mode of operation
in which said blocks of information bits are received at
said first rate and said second detecting means is used.

Hereby, it is possible to specify a first threshold that
the estimated quality must exceed before changing from
the first to the second detecting means. For example,
this enables specifying the amount of computational re-
sources that, according to the estimation, must be freed

before an alternative use of these is of interest, e.g. this may be the case when it is desired to use the computational resources freed only for a given task which requires a given amount of resources.

In accordance with a particularly expedient embodiment, said mobile station is adapted, when operated in said first mode or said second mode and when said estimated quality is above a predetermined second threshold, to change to a third mode of operation in which said blocks of information bits are received at a second rate higher than said first rate and said second detecting means is used. This is of major interest, since the resources freed, as a result of the use of the less complex second detection means when receiving a high quality signal, are used to increase the rate of receiving information in the mobile station, i.e. information throughput is increased.

Preferably, said mobile station is adapted, when operated in said third mode and when said estimated quality is below a predetermined third threshold, to change to said second mode of operation. In this situation channel conditions are found to be below a given level and therefore the transmission rate is decreased. Therefore, the rate at which blocks of information bits are received is decreased, and as a consequence fewer computational resources are needed by said receiver means. In this embodiment of the invention, said second detecting means is used. Therefore, the computational recourses freed – compared to the use of said first detecting means – can be used for other purposes or result in a lower power consumption. It is noted that said third threshold may be equal to said second threshold, if desired.

Preferably, said mobile station is adapted, when operated in said second mode or said third mode and when said es-

timated quality is below a predetermined fourth thresh-
old, to change to said first mode of operation. Hereby,
blocks of information bits having a low quality - accord-
ing to the performed estimation - can be detected, as
5   computational resources freed from the receiver means en-
able the use of the more complex and computation requir-
ing first detecting means. Hereby, a degradation in terms
of bit errors is avoided.

10 As mentioned above, the invention also relates to a
method as defined in the introductory portion of claim 6.
The method according to the invention is characterized by
further including: estimating the quality of one or more
of said distorted blocks of information bits, and, based
15 thereon, determining whether to perform said first detec-
tion or, when the quality of said received blocks of in-
formation bits is above a given level, performing a sec-
ond less computation-demanding detection of information
bits from said distorted information bits.
20
The advantages mentioned in connection with the corre-
sponding mobile station according to the invention are
achieved hereby.

25 Furthermore, the invention relates to a communications
system as specified in the introductory portion of claim
10. The system according to the invention is character-
ized by further including the means specified in the
characterizing portion of claim 10. It is noted that the
30 advantages mentioned in connection with the corresponding
mobile station according to the invention also apply to
such a system.

Expedient embodiments of the method and the system ac-
35 cording to the invention are defined in claims 7-9 and
claims 11-14, respectively.

The invention will be explained more fully below in con-
nection with a preferred embodiment and with reference to
the drawings, in which:

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fig. 1 illustrates a radio communications system,

fig. 2A shows a digital receiver in a mobile station ac-
cording to the prior art,

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fig. 2B shows a digital receiver in a mobile station ac-
cording to the invention,

fig. 3A is a first state diagram illustrating the opera-
15   tion of a receiver according to the invention,

fig. 3B is a second state diagram illustrating the opera-
tion of a receiver according to the invention, and

20   fig. 4 is a flow chart of a method according to the in-
vention.

The figures are schematic and simplified for clarity, and
they just show details which are essential to the under-
25   standing of the invention, while other details are left
out. Throughout, the same reference numerals are used for
identical or corresponding parts.

Figure 1 illustrates a cellular communications system as
30   an example of a radio communications system in which ra-
dio telephones or mobile stations contain circuitry to
permit transmission and reception of modulated signals,
thereby permitting two-way communication between the mo-
bile station 101 and remotely located transceivers known
35   as base stations 102, 103. In such systems, transmission
signals are normally produced as a modulation of a car-

rier signal with the digital symbols to be transmitted
via the communications link between a base station 102
and a mobile station 101.

5   As shown in the figure, in mobile radiophone communica-
tions systems, a plurality of base stations 102, 103 are
arranged so that each base station covers a respective
geographical area called a cell. These cells are grouped
together to provide a wide area system coverage. A mobile
10   station 101 located in a given cell communicates with the
base station therein via a communications link or commu-
nications channel. The base stations 102, 103 are nor-
mally formed into a regional or national network of tele-
phone switching offices that links the mobile subscribers
15   to the land based telephone network 104.

Often, when transmitting information from a first commu-
nications device to a second communications device, the
information is transmitted as blocks of information bits.
20   For example, in Time Division Multiple Access or TDMA
systems a number of digital signals are interleaved into
a single channel, i.e. the channel consists of a number
of sub-channels providing service to a number of communi-
cations devices instead of a single one. Therefore, when
25   transmitting information to a given communications de-
vice, the information is transmitted in bursts where each
burst consists of a number of data symbols or information
bits. The communication is performed during continuously
repeating intervals of time or time periods - so-called
30   time slots - in which two devices are able to intercon-
nect. Therefore, the blocks of information bits transmit-
ted between a given base station 102 and a given mobile
station 101 are transmitted at a given rate.

35   It is well known that communications links between first
and second communications devices in a radio communica-

tions system can be of different quality. When the infor-
mation is transmitted via the communications link, the
transmitted signals are exposed to distortion, and as a
result the signals received in the second communications
5   device are distorted versions of the signals originally
sent. The distortion, which can have a significant influ-
ence on the transmission quality and/or reception of
voice and data, depends on the quality of the communica-
tions link. For example, the quality of the signals re-
10 ceived in a mobile station 101 may depend on the distance
between the mobile station 101 and the base station 102,
on different reflections of the radio waves transmitted
between the base station 102 and the mobile station 101,
and/or on noise from the area of operation.

15

When blocks of digital information are transmitted from a
first communications device to a second communications
device via a communications link, blocks of distorted in-
formation bits may be received in the second communica-
20 tions device. Therefore, when receiving bursts or blocks
of digital information bits, detection of the information
bits has to be performed on the basis of the received
distorted information in order to recover the information
bits originally sent.

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Fig. 2A illustrates a digital receiver in a mobile sta-
tion according to the prior art. The receiver includes
receiver means 212 and first detection means 206. The re-
ceiver means 212 is adapted, as a result of a transmis-
30 sion of blocks of information bits from a base station
over a communications link, to receive blocks of dis-
torted information bits, whereas the first detection
means 206, which is an equalizer in the shown example, is
adapted to detect information bits from said distorted
35 information bits.

The receiver means 212 can be implemented in many ways.
In the shown example, the receiver means 212 includes a
front-end receiver 202, an analogue to digital converter
203, a digital filter 204, and a synchronisation and
5 channel estimation unit 205. The front-end receiver 202
first processes the signal received via the antenna 201
by performing the following steps. Firstly, a band-pass
filtering is performed on the received signal in order to
filter out the desired frequency band. Secondly, the sig-
10 nal is down-converted to baseband by a mixer. Finally, a
low-pass filtering is carried out in order to filter out
the mirror signal generated by the mixer.

The output signal from the front-end receiver 202 is A/D
15 converted by the analogue to digital converter 203. The
digital filter 204 illustrates that some additional fil-
tering is then carried out to cope with adjacent channel
interferers. The sampled signal, i.e. the output signal
from the digital filter 204, is fed to the synchronisa-
20 tion and channel estimation unit 205. In some cellular
systems, such as the Global System for Mobile Communica-
tions or GSM, the information is sent in burst format in
which each burst includes a training sequence in the mid-
dle of the burst and includes information sequences on
25 each side of the training sequence. The training sequence
is used for synchronisation and channel estimation. The
synchronisation and channel estimation unit 205 is
adapted to perform a synchronisation and channel estima-
tion and, therefore, the output therefrom includes infor-
30 mation on the position of the pilot symbols in the burst
as well as an estimation of the channel pulse response.

The equalizer 206 that will demodulate the transmitted
symbols then uses this information to minimise the effect
35 of intersymbol interference (ISI) introduced by the
physical channel. The demodulated symbols together with a

probability measure of each symbol (each bit in the sym-
bol) are then fed to the interleaver 207 which splits up
consecutive bit errors, as the following channel decoder
208 is not well suited to remedy such errors. The channel
5   decoder 208 then decodes the block of data, which is then
passed to higher layers. It is noted that a block of data
is associated with a time-slot in a time division multi-
ple access (TDMA) system.

10   Using multiple time-slots will thus improve the through-
put drastically. Using multiple time-slots, however, also
has some associated problems since the signal processing
of the received symbols requires a powerful digital sig-
nal processor (DSP) in terms of instructions per second
15   (IPS). The invention enables the use of several time-
slots in an IPS limited system by trading IPS used in one
unit (e.g. equaliser) to IPS in a second unit (e.g. chan-
nel decoder) if some defined thresholds are fulfilled.
Since the number of time-slots granted is decided by the
20   network, this will initiate a renegotiation of service in
order to increase the number of time-slots.

The invention uses information on the propagation condi-
tions of the physical channel to decide whether it is
25   possible to disable units or to use a less complex method
(in terms of IPS) with only marginal or no loss in re-
ceiving performance or not. If this is possible, the to-
tal number of IPS spent will decrease and may allow for
more time-slots, i.e. increase the transmission rate of
30   the blocks of information bits. That is, the number of
time-slots possible to process is dynamically determined
by observing the actual channel conditions. The invention
includes the possibility of increasing or decreasing the
number of time-slots depending on the channel condition
35   by initiating a renegotiation of service.

On the basis of the estimation, i.e. the measurement of
the actual receiving condition of the physical channel, a
decision of whether it is possible to disable or to use
less complex processing units with only negligible per-
5 formance loss or not is taken. If this is possible and
the IPS freed hereby allows the receiver to process more
time-slots, a renegotiation of service is called for. The
result of the renegotiation of service may or may not be
that the mobile station is allowed to use more time-
10 slots.

Figure 2B is an example of a digital receiver in a mobile
station according to the invention. In addition to the
elements shown in figure 2A, the mobile station according
15 to the invention includes second detecting means 213
adapted, when the quality of said received blocks of in-
formation bits is above a given level, to detect informa-
tion bits from said distorted information bits using less
computation resources than said first detecting means
20 206. Further, as shown in the figure, the mobile station
includes estimation means 211 adapted to estimate the
quality of received blocks of information bits and, based
thereon, to determine whether to use said first detecting
means 206 or said second detecting means when detecting
25 information bits. It is noted that the receiver means
212B in this embodiment differs from the receiver means
212 only by being connected to the estimation means 211.

In the shown example, the estimation means 211 includes a
30 channel condition estimator 209 and a control unit 210.
The channel condition estimator 209 collects information
on the channel quality. This can be carried out in sev-
eral ways, not limited to the invention. It is noted that
estimation of the quality of a communications channel is
35 well known in the field of telecommunication. For exam-
ple, the quality estimation may be performed as an esti-

mation of the signal/noise ratio of the received signal.
The estimated quality is then fed to the control unit 210
that determines whether the channel quality is sufficient
or not to disable or change method in a processing unit,
5 e.g. in the equalizer where a change of method could be
to change from Maximum Likelihood Sequence Estimation
(MLSE) operation to Decision Feedback Equalizer (DFE) op-
eration, thereby using fewer computational resources. If
so, and if the number of disablings/changes of method is
10 sufficient to process more time-slots, the control unit
disables/changes the unit/units and requests a renegotia-
tion of service. In the shown embodiment, the control
unit 210 is adapted to select the method of detection to
be used by selecting the first or second eqalizer
15 206,213. A second threshold on the estimate of the chan-
nel can be used to determine when a simpler equalizer
(using fewer IPS) can be used in conjunction with a
stronger channel coding, such that the increase in data
rate due to the larger number of time slots, offsets the
20 decrease in data rate due to the stronger channel coding.

In the shown embodiment, the channel condition estimator
209 is connected to the output of the analogue to digital
converter 203, the digital filter 204, and the synchroni-
25 sation and channel estimation unit 205. This illustrates
that the channel condition estimator 209 may use several
signals when estimating the quality of the channel. For
example, this is advantageous as the noise contribution
related to different types of noise, e.g. adjacent chan-
30 nel noise, cochannel noise and/or thermal noise, can be
estimated now.

Figure 4 is a flow chart illustrating a method of trans-
mitting electronic information according to the inven-
35 tion. The electronic information is transmitted from a
first communications device to a second communications

device in a radio communications system. In step 401,
blocks of information bits, transmitted at a first rate
from said first communications device to said second com-
munications device via a communications link, are re-
5   ceived as blocks of distorted information bits. In step
402, the quality of received blocks of information bits
is estimated in order to estimate the quality of the com-
munications link between the first and second communica-
tions devices. In step 403, a determination of whether to
10 perform the first detection, or, when the quality of the
received blocks of information bits is above a given
level, perform a second less computation-demanding detec-
tion of information bits from the received distorted in-
formation bits, is carried out. The determination in step
15 403 is based on the quality estimation performed in step
402. In step 404, the first or second detection selected
in step 403 is performed.

Preferably, the estimation and the determination of the
20 steps 402 and 403 are performed on the fly, i.e. at least
once for every new block of distorted information bits
received, in order to select the optimal detection means
to be used. Hereby, as described in relation to figure 3A
and 3B, the mobile station can be operated in different
25 states or modes depending on the value of the estimated
quality, i.e. when the estimated quality is above or be-
low given predetermined thresholds.

Fig. 3A is a state diagram illustrating the operation of
30 a receiver in a communications device such as a mobile
station according to the invention. When receiving elec-
tronic information from a base station, the mobile sta-
tion is operated in one of the three modes or states S1,
S2 or S3. In state S1, illustrated by 301 in the figure,
35 blocks of information bits, which are transmitted from a
base station at a first rate via a communications link,

are received by the mobile station. Due to distortion in
the communications link, the transmitted blocks of infor-
mation bits are received as blocks of distorted informa-
tion bits. The first detecting means in the mobile sta-
5   tion which is adapted to detect information bits from
said distorted information bits, is used in the state S1.

The mobile station also includes estimation means adapted
to estimate the quality of said communications link or
10   the quality of the received information bits and, based
thereon, to determine whether to use said first or said
second detecting means when detecting information bits,
i.e. whether to continue operating in state S1 or to
start operating in state S2. In the shown embodiment, the
15   determination is performed by comparing the estimated
quality q_e with a predetermined first threshold t_1. When
the estimated quality is above the first threshold t_1
(i.e. when $q_e > t_1$), the operating state is changed from
S1 to S2 - otherwise the operating state continues to be
20   S1.

In state S2 - like in S1 - blocks of information bits are
transmitted from a base station to the mobile station at
a first rate. But in contrast to state S1, in state S2,
25   the second detecting means, adapted to detect information
bits from the received distorted information bits using
fewer computation resources than the first detecting
means, is used. This operation is possible as a result of
the high quality of the communications link and, as a
30   consequence, the high quality of the information bits re-
ceived. When the estimated quality is above a predeter-
mined second threshold t_2 ($q_e > t_2$) the operating state is
changed from S2 to S3. If, on the other hand, the esti-
mated quality is below a predetermined fourth threshold
35   t_4 ($q_e < t_4$) the operating state is changed from S2 to S1.
Otherwise, i.e. if the estimated quality is between the

fourth and the second thresholds ($t_4 < q_e < t_2$), the oper-
ating state continues to be S2. It is noted that opera-
tion in state S2 is advantageous over operation in state
S1 due to a lower power consumption as a result of the
5 fewer computation resources required.

In state S3 the second less computation demanding detec-
tion means is used - like in S2 - but blocks of informa-
tion bits from the base station are received at a second
10 rate higher than said first rate. For example, in a TDMA
system, more time-slots are used when transmitting data
from the base station to the mobile station. This opera-
tion is possible as a result of the computation resources
freed because of using the second detecting means instead
15 of the first detection means due to the high quality of
the communications link. When the estimated quality is
below a predetermined third threshold t_3 ($q_e < t_3$), the
operating state is changed from S3 to S2 - otherwise the
operating state continues to be S3. It is noted that op-
20 eration in state S3 is advantageous over operation in
state S2 when a high data through-put is desirable, e.g.
when transmitting non-speech data.

Fig. 3B is a state diagram illustrating the operation of
25 a receiver in a communications device such as a mobile
station according to another embodiment of the invention.
In this embodiment the mobile station in only operated in
the states S1 and S3. This embodiment is expedient when
only a high data through-put is desirable. Likewise, an
30 embodiment having only the states S1 and S2 could be used
when only a low power consumption is desirable. These
situations may be achieved when the above-mentioned first
and second, and third and fourth thresholds, respec-
tively, are given the same values.

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As the difference in operation of a mobile station be-
tween the states S1 and S2 does not affect the operation
of the base station, the change of operation between S1
and S2 can be performed without informing the base sta-
5   tion. In contrast thereto, the change of operation be-
tween the states S2 and S3 or between the states S1 and
S3 can only be performed when both the base station and
the mobile station so permit. For example, the base sta-
tion must be able to transmit blocks of information bits
10   at the higher rate. In other words, the base station and
the mobile station must agree before the change of opera-
tion between the states S2 and S3 takes place. As is well
known from the prior art, in order to reach an agreement
a so-called negotiation of service may take place. An ex-
15   ample is given below.

A mobile station may propose an initial service configu-
ration at the channel connection origination or may pro-
pose new service configuration during channel operation.
20   If the mobile station proposes a service configuration
which is acceptable to the base station, they both begin
using the new service configuration. If the mobile sta-
tion proposes a service configuration that is not accept-
able to the base station, the base station can reject the
25   proposed service configuration or propose an alternative
service configuration. The mobile station can reject the
service configuration proposed by the base station or
propose yet another service configuration to be used. It
is noted that the negotiation process described above may
30   include more or less steps, and that it can also be per-
formed with the roles reversed, i.e. the base station
initiates the negotiation.

Some preferred embodiments have been shown in the forego-
35   ing, but it should be stressed that the invention is not
limited to these, but may be embodied in other ways

within the subject-matter defined in the following
claims. For example, even though the examples given re-
late to a mobile station receiving information from a
base station, the method according to the invention is
5   not limited to be used in a mobile station. In general,
the method according to the invention may be used when
receiving, in a second communications device, blocks of
information bits, transmitted at a first rate from a
first communications device to a second communications
10   device via a communications link, as blocks of distorted
information bits.